

# Transporting Stratospheric Water Vapor in the GMI Combo Model

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## **Motivation:**

Stratospheric water vapor in the current Combo model is climatological, and accounting for PSC processes as well as changes in CH<sub>4</sub> emissions is clumsy. Can we improve this by transporting water in the stratosphere?

# Methodology

1. Advection
2. Convection
3. Deposition
4. Add Trop Water
5. Chemistry

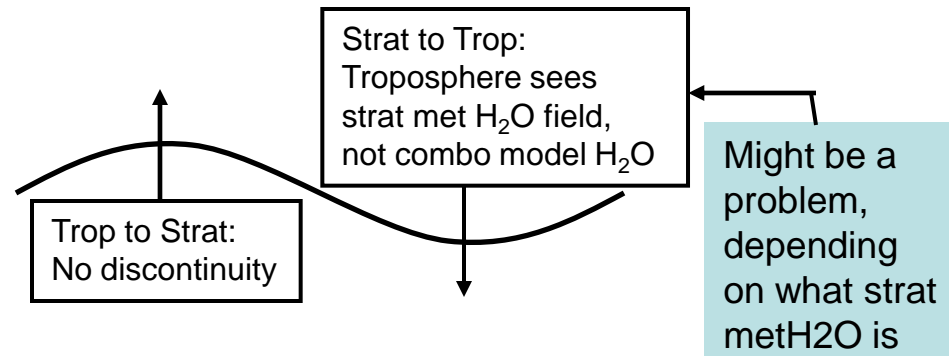
Currently  $A = 1$ , meaning Met  $H_2O$  replaces transported water below tropopause at every time step

$$H_2O(t+dt) = H_2O(t) + A \times ( \text{Met}H_2O(t) - H_2O(t) )$$

Independently Transported Species:

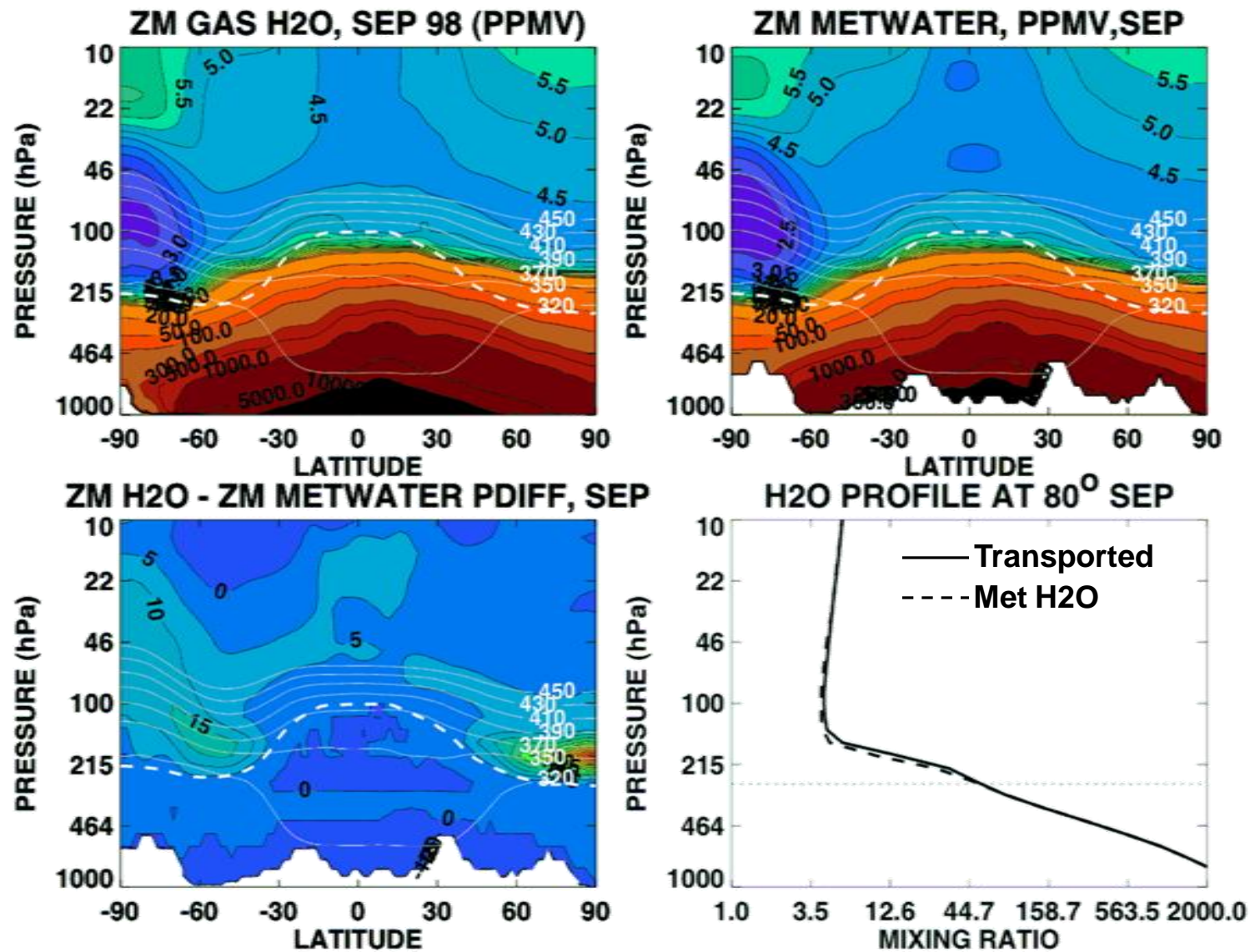
$H_2O$   
 $H_2OCOND$   
 $HNO_3$   
 $HNO_3COND$

Need to transport separately to allow for separate nucleation and evaporation temperatures



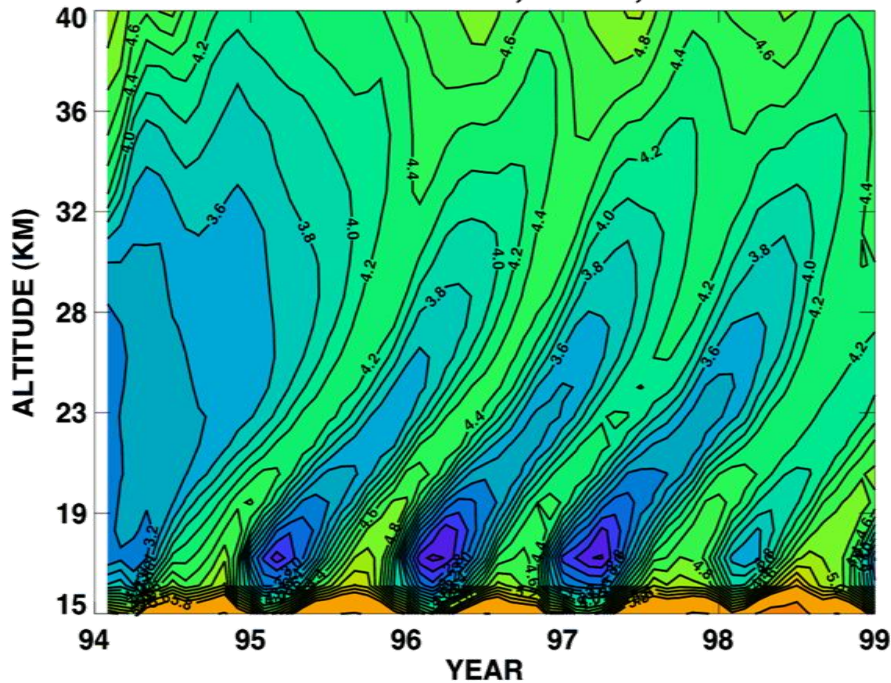
## Run Description

- 5 year run.
- GEOS4 AGCM with 1994 - 1998 SSTs data set.
- 2 x 2.5 resolution.
- Combo model is modified version of 10/31/07 download.
- 1st 4 years run with bad “ilat” specification, resulting in PSC scheme only being called at pressures lower than 120 hPa, with max pressure specification at high SH lats being sometimes as low as 36 hPa.
- Reran last year several times (~4 days/year @ 64 nodes); best results with latitudinally-invariant pmax of 300 hPa. (Operationally probably best to set lower bound as tropopause.)
- Also ran 1 year of GEOS 4 DAS winds (year 2004), initialized from December 1998 of AGCM run.

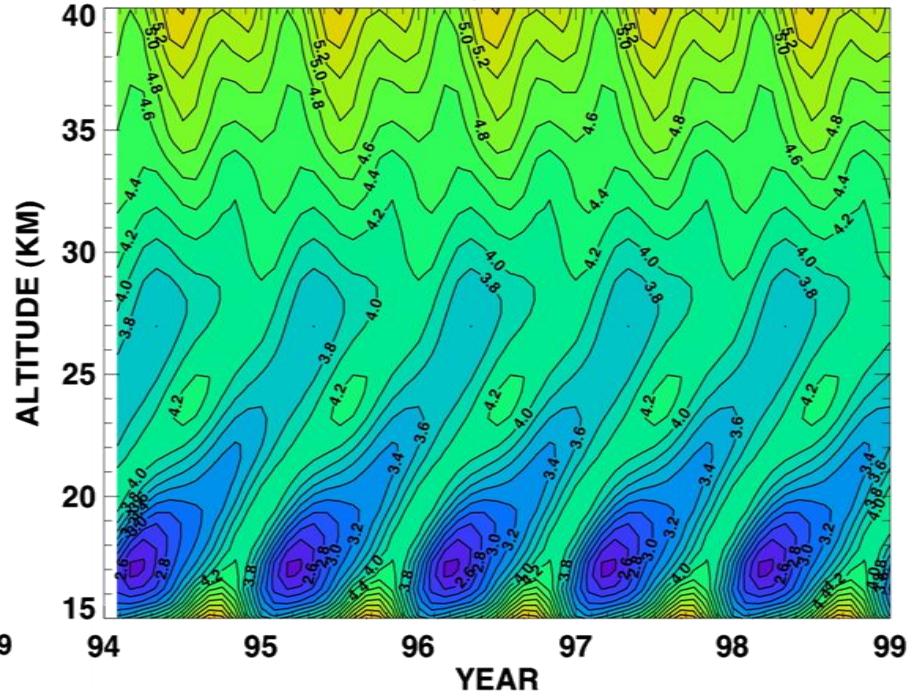


MetH<sub>2</sub>O stratosphere is HALOE/MLS climatology. Transported H<sub>2</sub>O in stratosphere agrees pretty well overall. Transported H<sub>2</sub>O tends to be higher just above tropopause at mid-to-high lats. Diffs could also be due to interannual variability.

**ZM GAS PHASE H<sub>2</sub>O, PPMV, LAT = 2°**

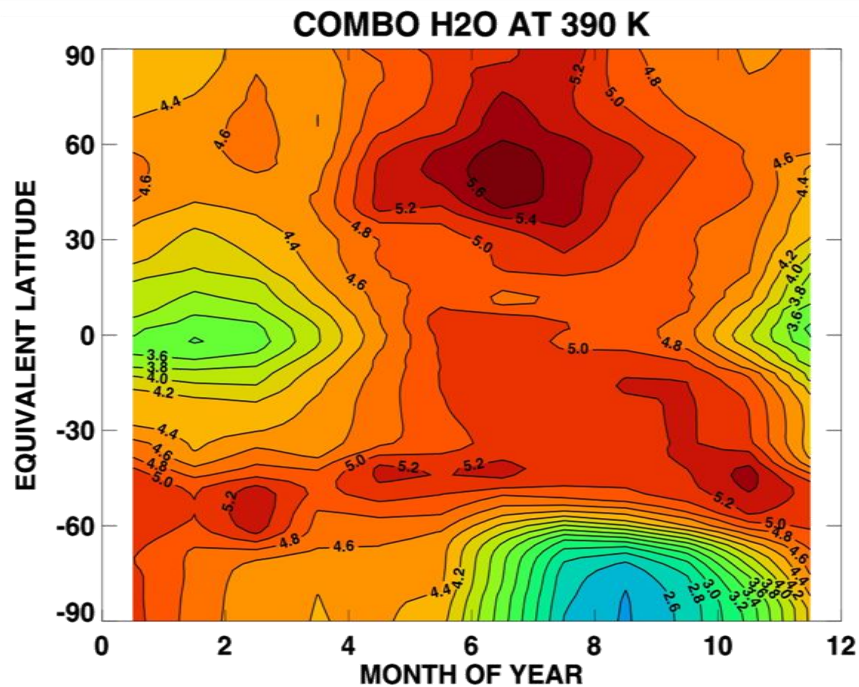
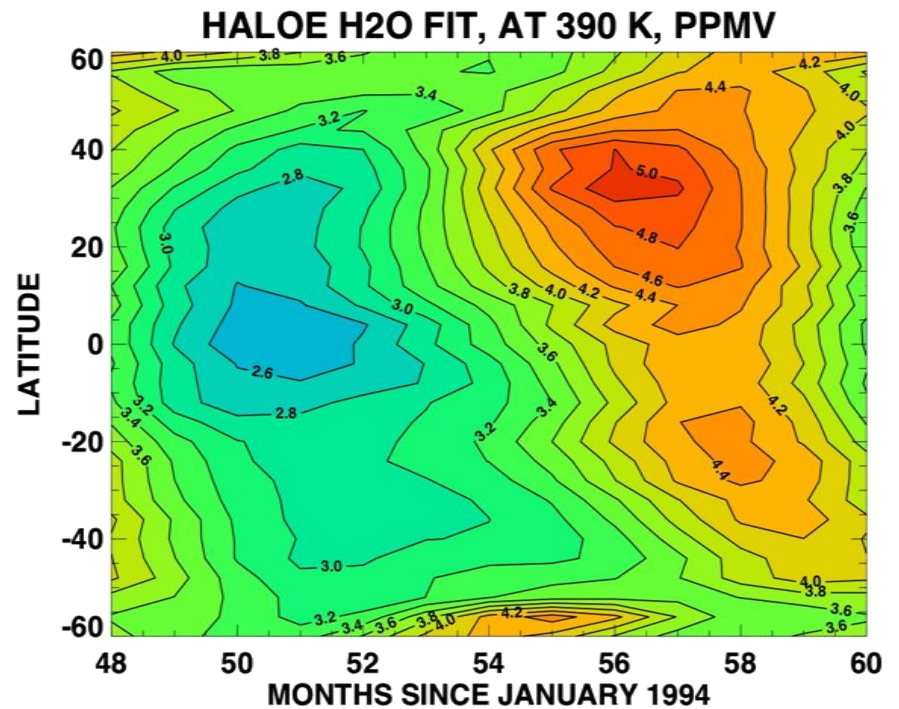
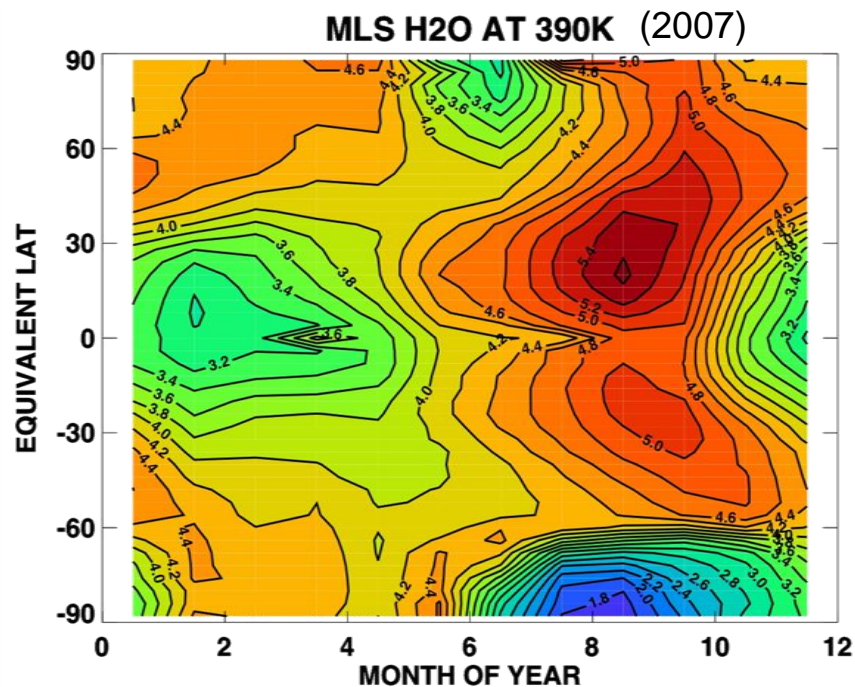


**HALOE H<sub>2</sub>O FIT, PPMV, EQUATOR**



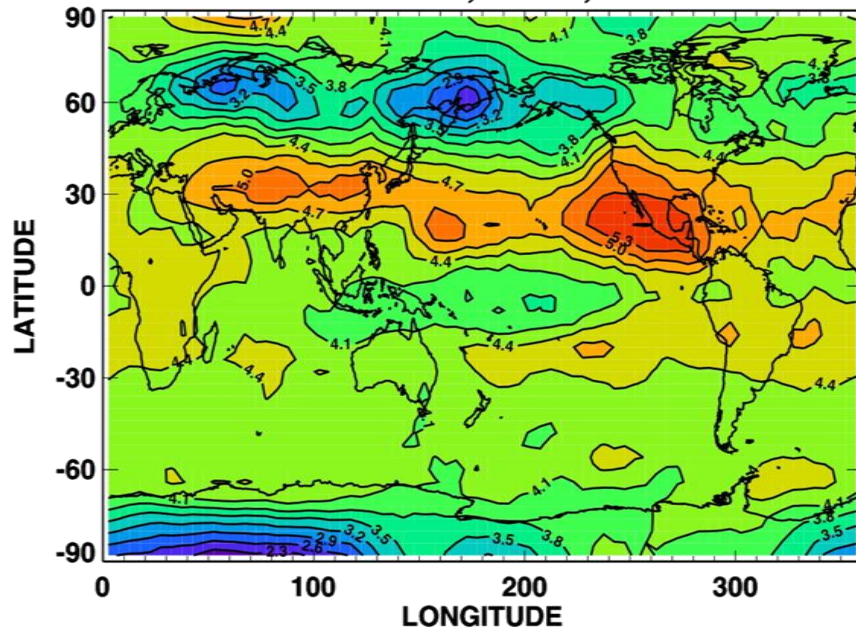
Model exhibits lower stratospheric ascent rate of  $\sim 0.3$  mm/s, consistent with HALOE obs, with ascent rates increasing above 20 - 25 km as observed. Tape recorder signal remains coherent to higher altitudes ( $> 30$  km) than observed, due to lack of QBO and perhaps a weak SAO. US values are slightly smaller than HALOE observation, and there may be a small decreasing trend. Lower stratospheric minima and maxima agree well with obs.

HALOE v19 H<sub>2</sub>O data, 1994 - 1998, 4° latitude bins, at equator, regressed to annual and semiannual harmonics only, as in Randel et al. [2001].

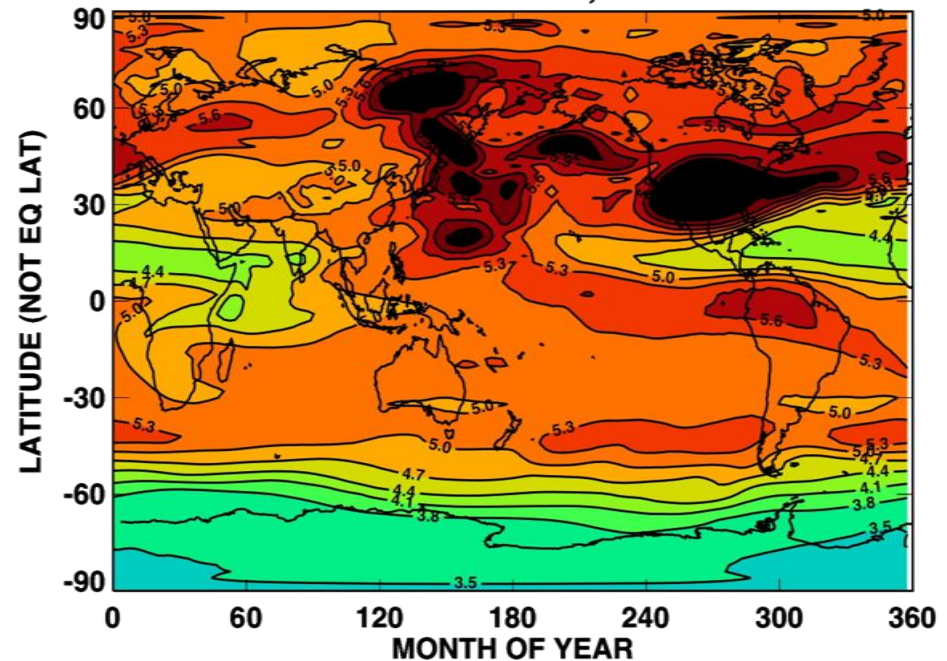


At base of overworld, GMI transported H<sub>2</sub>O shares similarities with MLS H<sub>2</sub>O. Evidence of poleward transport extending from tropical minimum in February is weak. NH H<sub>2</sub>O Max (associated with NH summer monsoon in atmosphere) is right magnitude, but occurs 2 months too early and ~20° poleward of observed position. SH H<sub>2</sub>O max in model occurs too late. Model exhibits high H<sub>2</sub>O along stormtracks in SH, which is not observed. SH polar minima are higher than observed in MLS, perhaps due to interannual variability, but timing is correct.

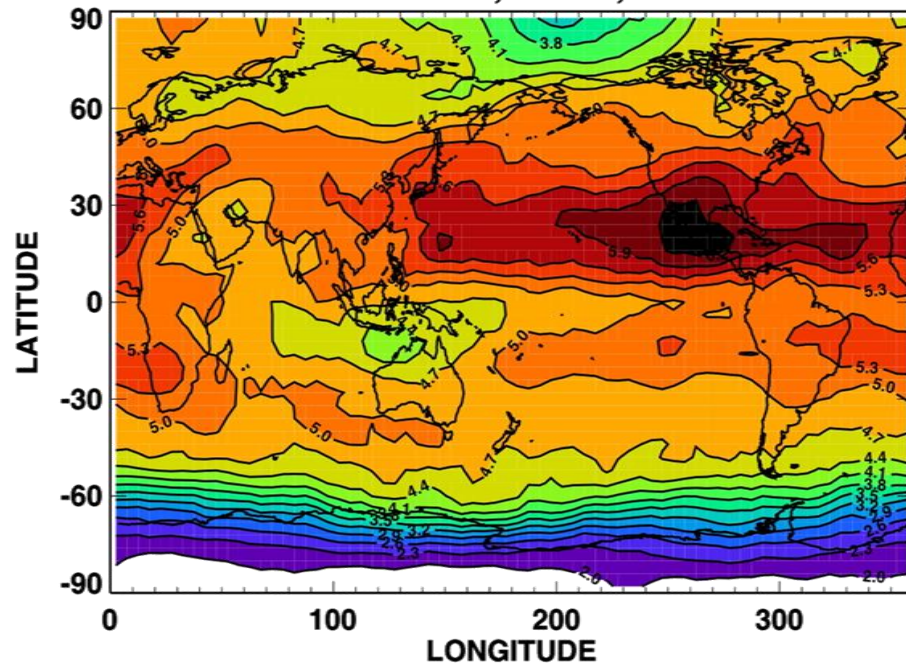
**MLS GAS H<sub>2</sub>O, PPMV, JUL 390**



**H<sub>2</sub>O AT 390 K, JUL**

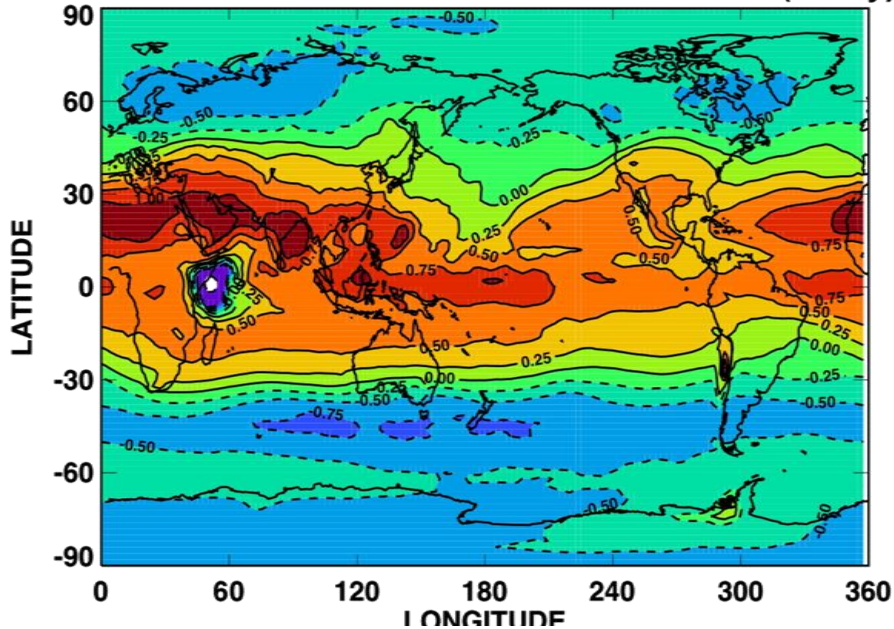


**MLS GAS H<sub>2</sub>O, PPMV, SEP 390**

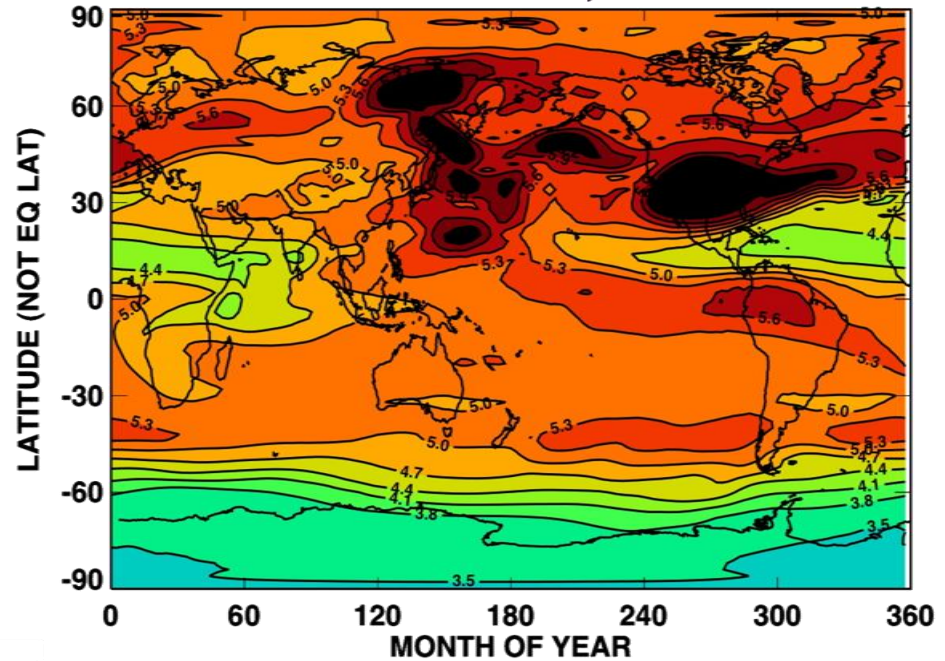


In July, MLS H<sub>2</sub>O maxima occur over Central America, western Pacific and Tibetan plateau. Model has larger maxima over CONUS and western Pacific as far north as 70°. The MLS Central American maximum is stronger in September and is apparently responsible for annual cycle peak.

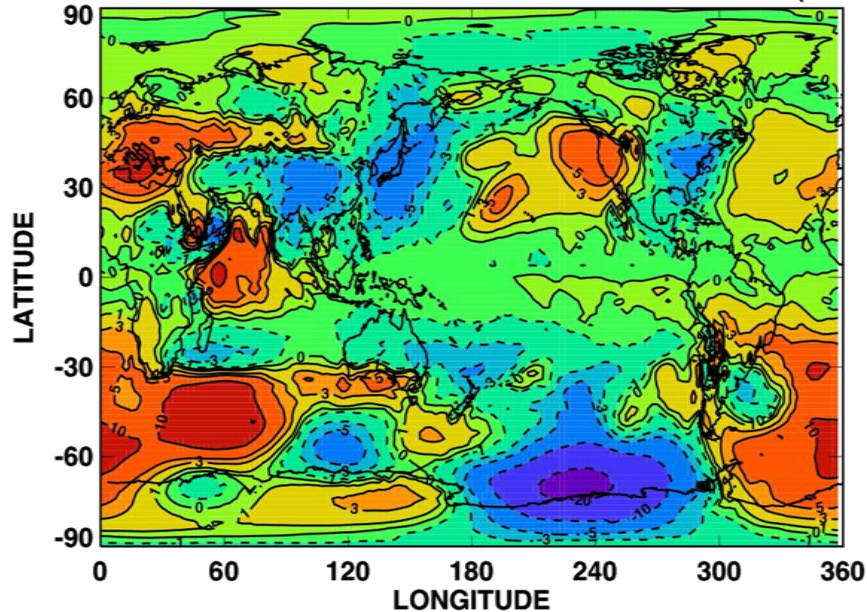
GEOS4 JUL 1998 HEATING RATE AT 390K (K/day)



H2O AT 390 K, JUL

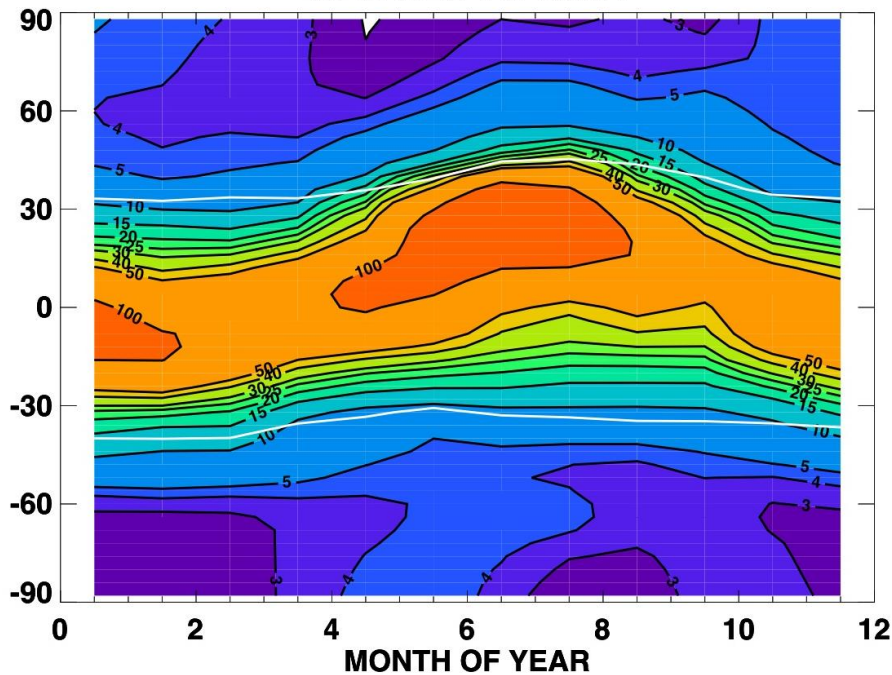


GEOS4 JUL 1998 PRESSURE VELOCITY AT 390K (hPa/day)

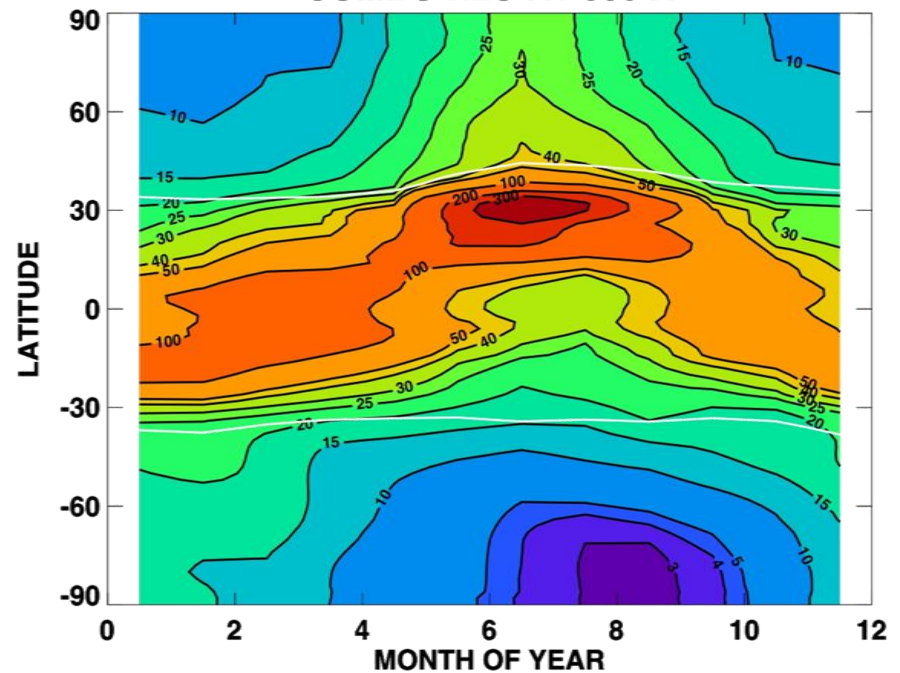


GEOS 4 Heating rates at 390K are positive between  $\sim (30S - 40N)$ , and negative poleward. Morphology of high H2O values does not reflect heating rates. Vertical pressure velocities are generally negative (i.e. upwelling) in NH where 390K H2O mixing ratios are large.

**MLS H<sub>2</sub>O AT 350K**

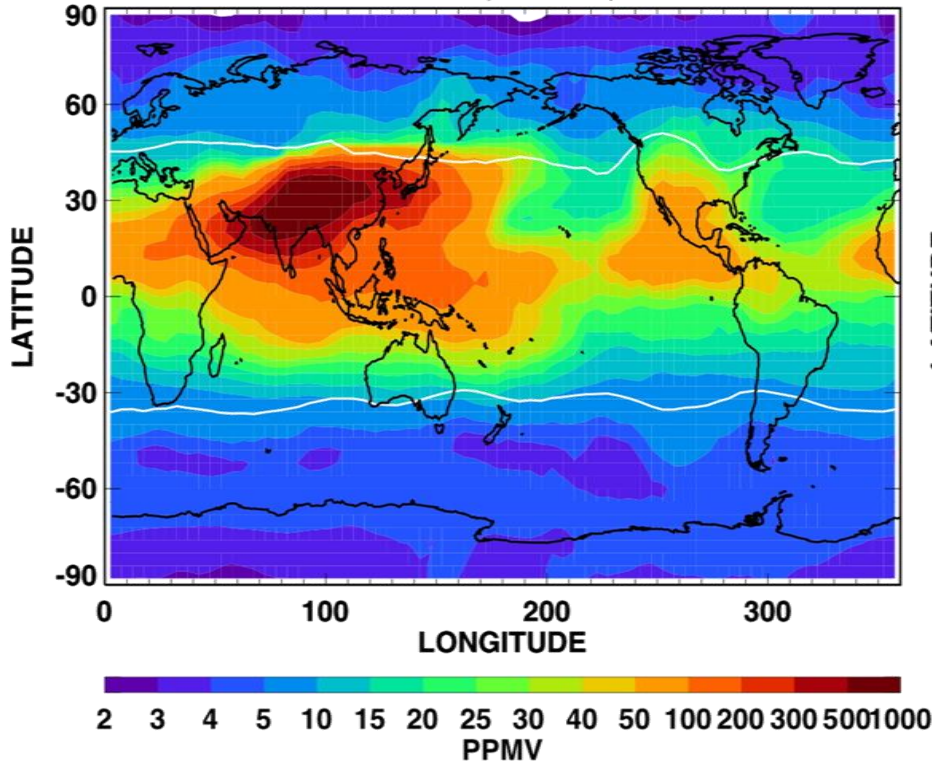


**COMBO H<sub>2</sub>O AT 350 K**

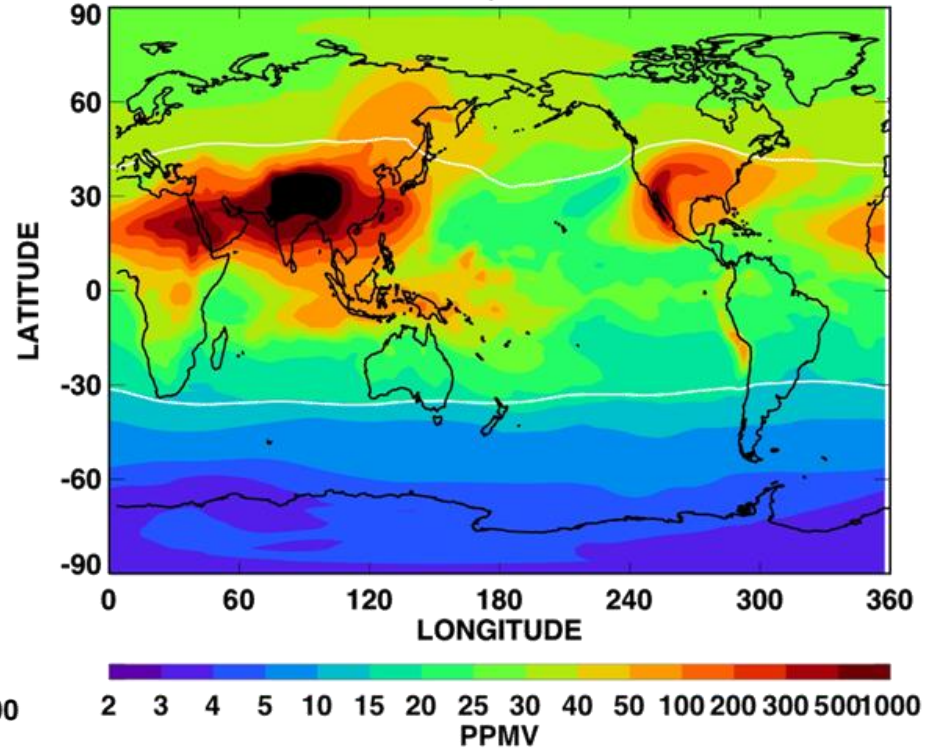


The 350 K surface is approximately coincident with the 215 hPa surface, and crosses from the tropical UT into the lowermost stratosphere poleward of the tropopause. Model H<sub>2</sub>O is higher than observed in tropics, where water vapor is met water field, and shows substantially higher values than observed by MLS in the LMS. MLS values are extremely low, lower even than at the tropical cold point from which they are supposed to have been transported.

MLS GAS H<sub>2</sub>O, PPMV, JUL 350

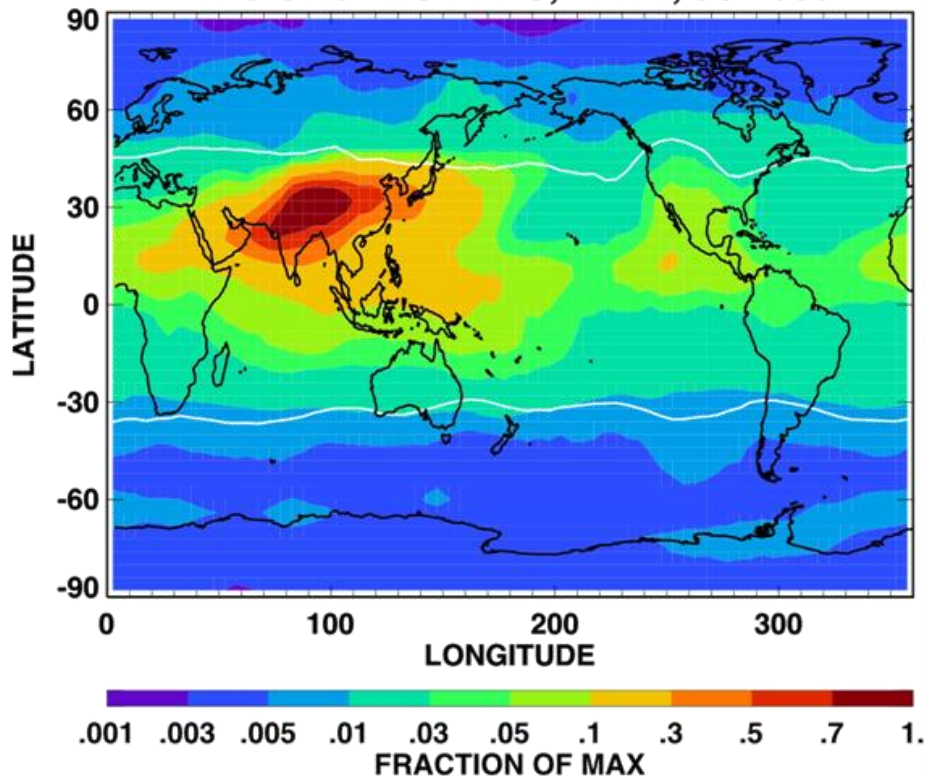


H<sub>2</sub>O AT 350 K, MONTH = JUL

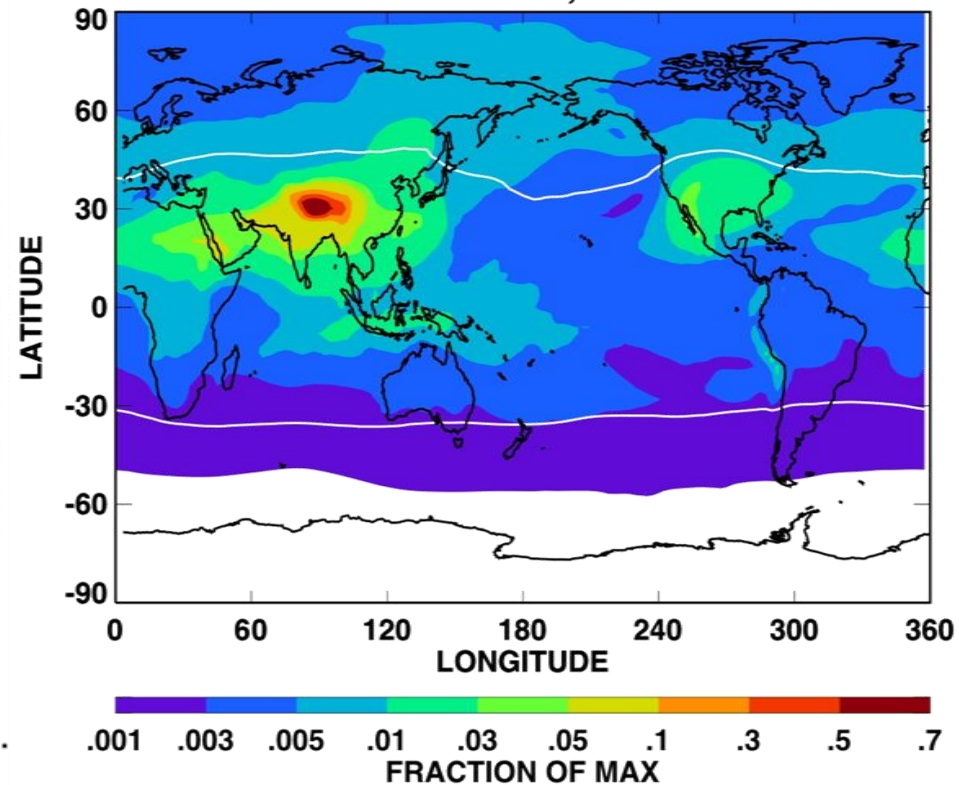


In NH LMS, MLS mixing ratios are < 15 ppmv. Combo model H<sub>2</sub>O mixing ratios range from 25 - 100 ppmv in LMS. Model H<sub>2</sub>O in LMS appears to have been transported from maximum over northern India and Tibetan plateau, with secondary contribution from west coast of northern and central America. Model shows ridge of high H<sub>2</sub>O running along west coast of South America that is not observed.

MLS GAS H<sub>2</sub>O FRAC, PPMV, JUL 350

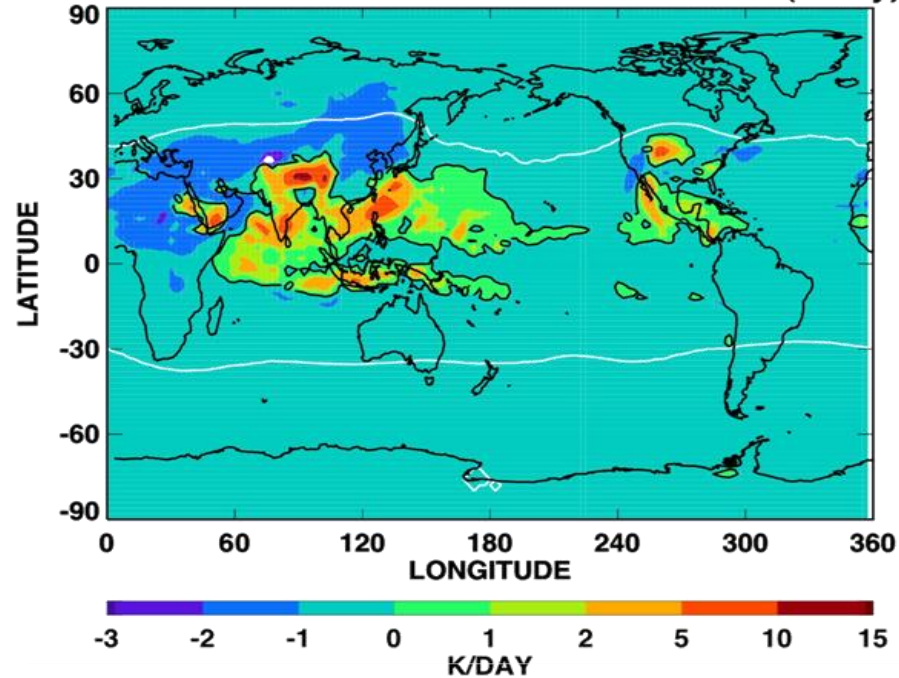


H<sub>2</sub>O FRAC AT 350 K, MONTH = JUL

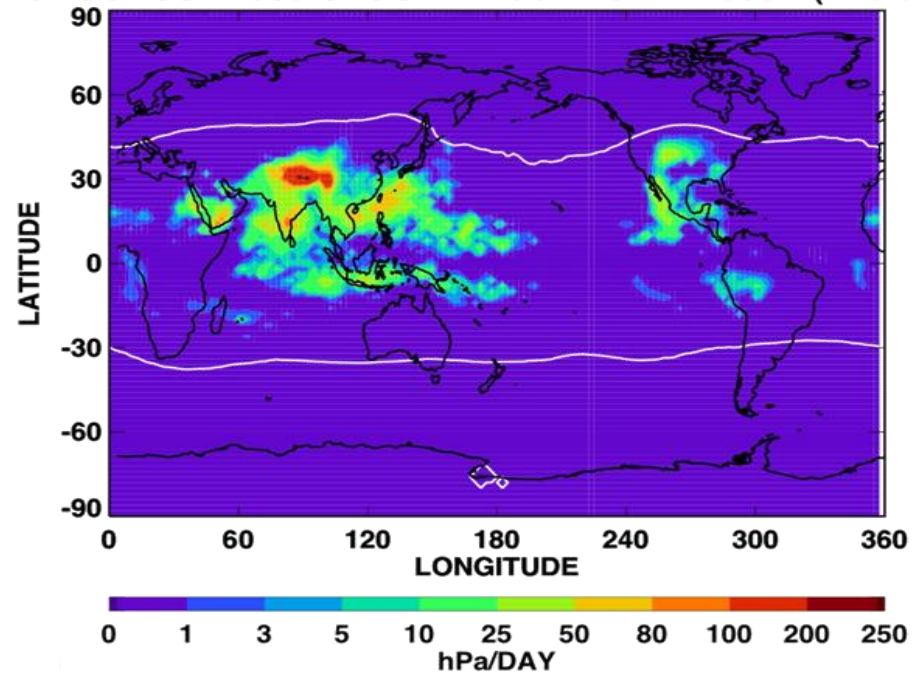


Plotting fraction of H<sub>2</sub>O maximum on 350 K surface shows that Combo model distribution is more sharply peaked than observed by MLS. In NH LMS, model H<sub>2</sub>O fraction is smaller than seen in MLS. This indicates that model tropopause transport barrier may be fine, and that excessive H<sub>2</sub>O in the LMS is due to excessive vertical transport of H<sub>2</sub>O in tropics over Tibetan plateau.

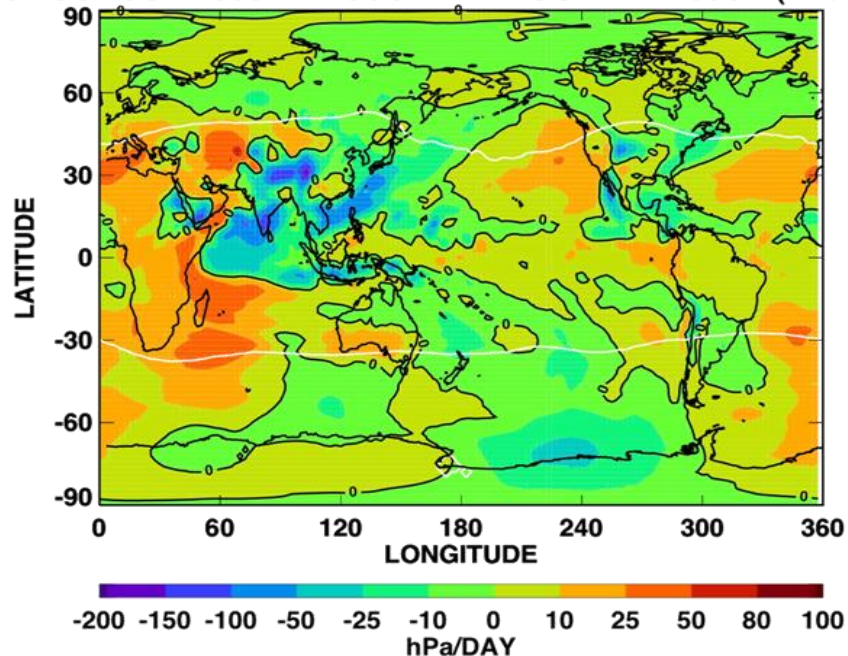
GEOS4 JUL 1998 HEATING RATE AT 350K (K/day)



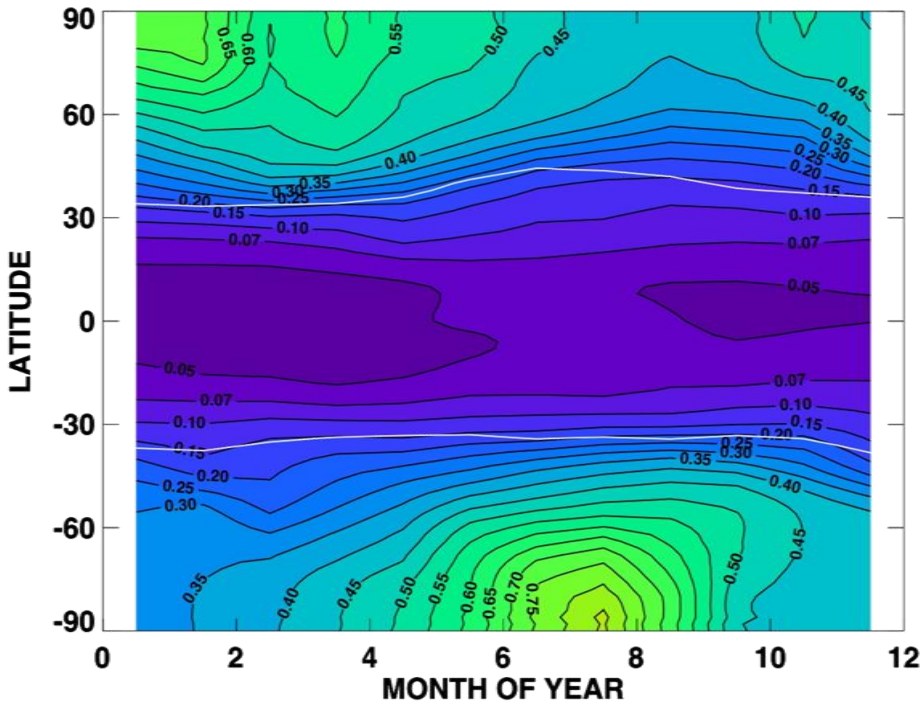
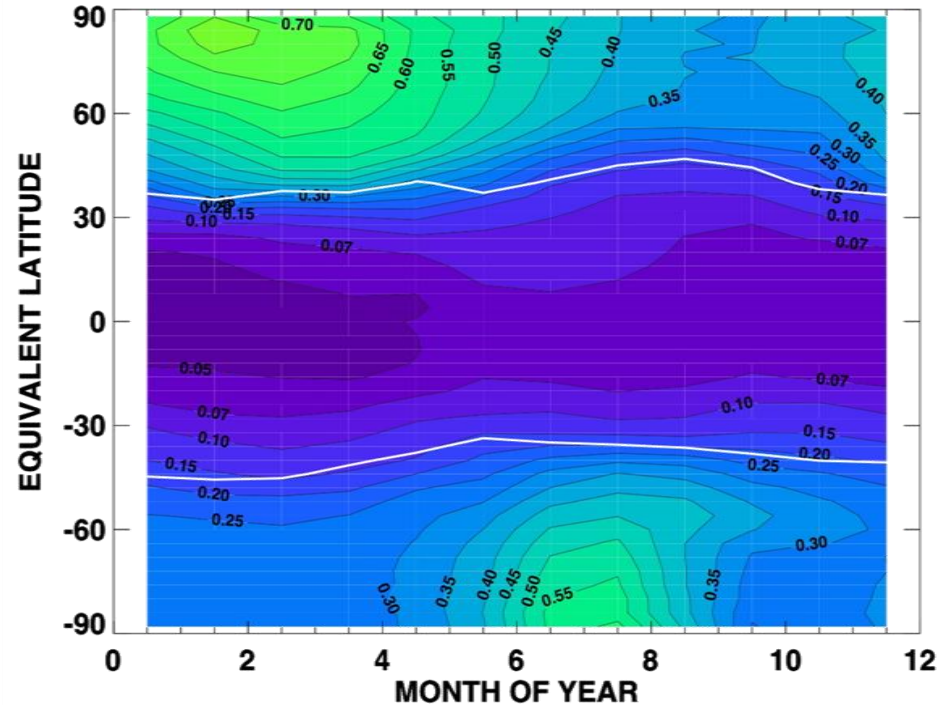
GEOS4 JUL 1998 CLOUD MASS FLUX AT 350K (hPa/day)



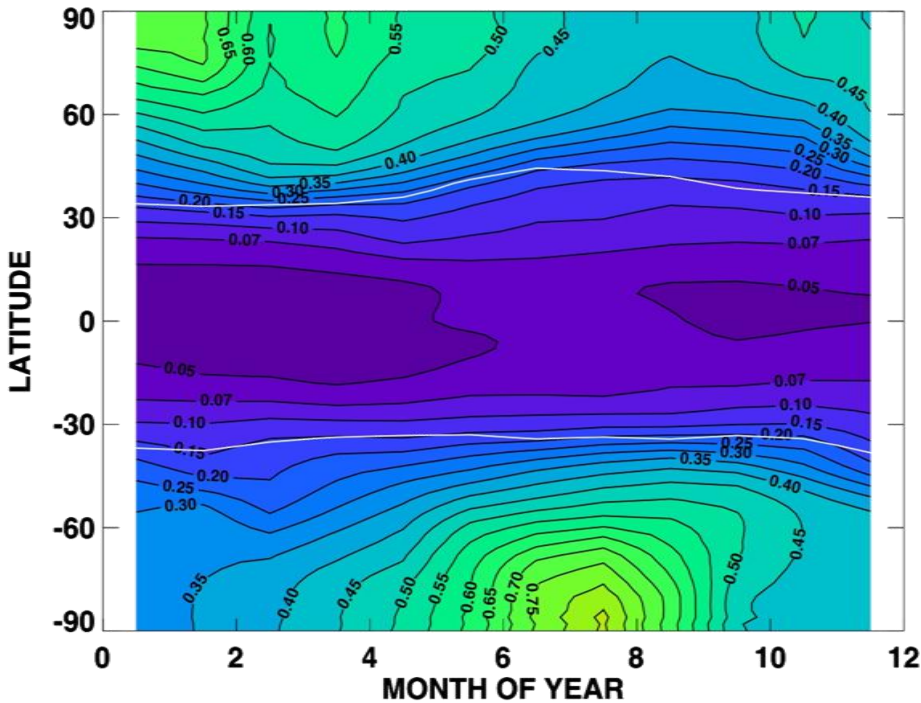
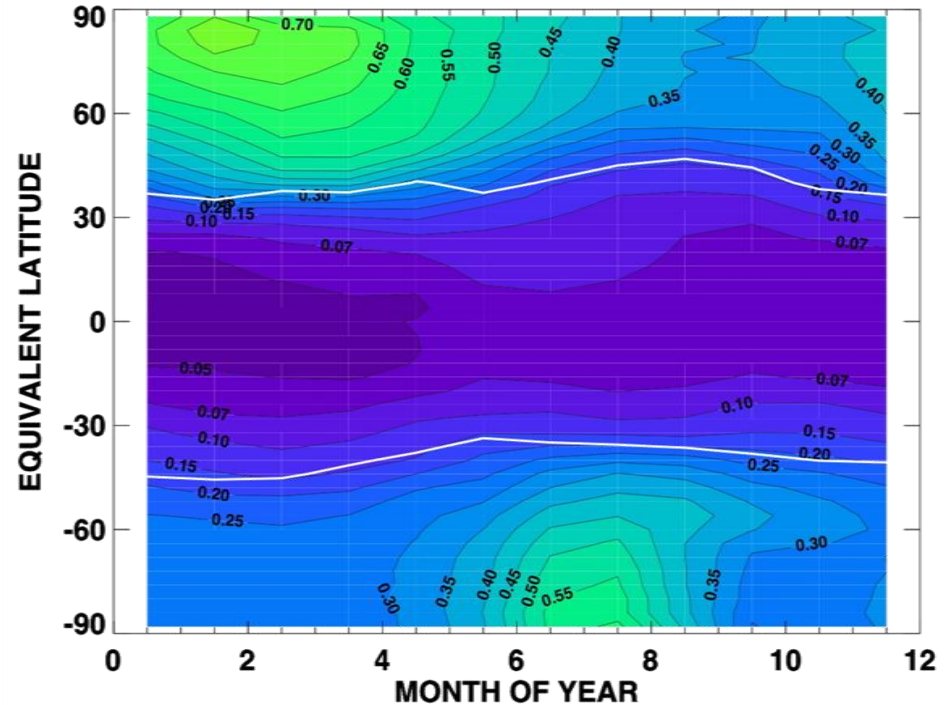
GEOS4 JUL 1998 PRESSURE VELOCITY AT 350K (hPa/day)



Convective heating rates, cloud mass fluxes and negative pressure velocities maximize over Tibetan plateau & southeast Asia, indicating both large-scale and convective contributions to vertical transport to 350 K isentrope. In LMS, negative heating rates and zero convective mass fluxes indicate any transport from below which might contribute to high water vapor mixing ratios is anomalous.

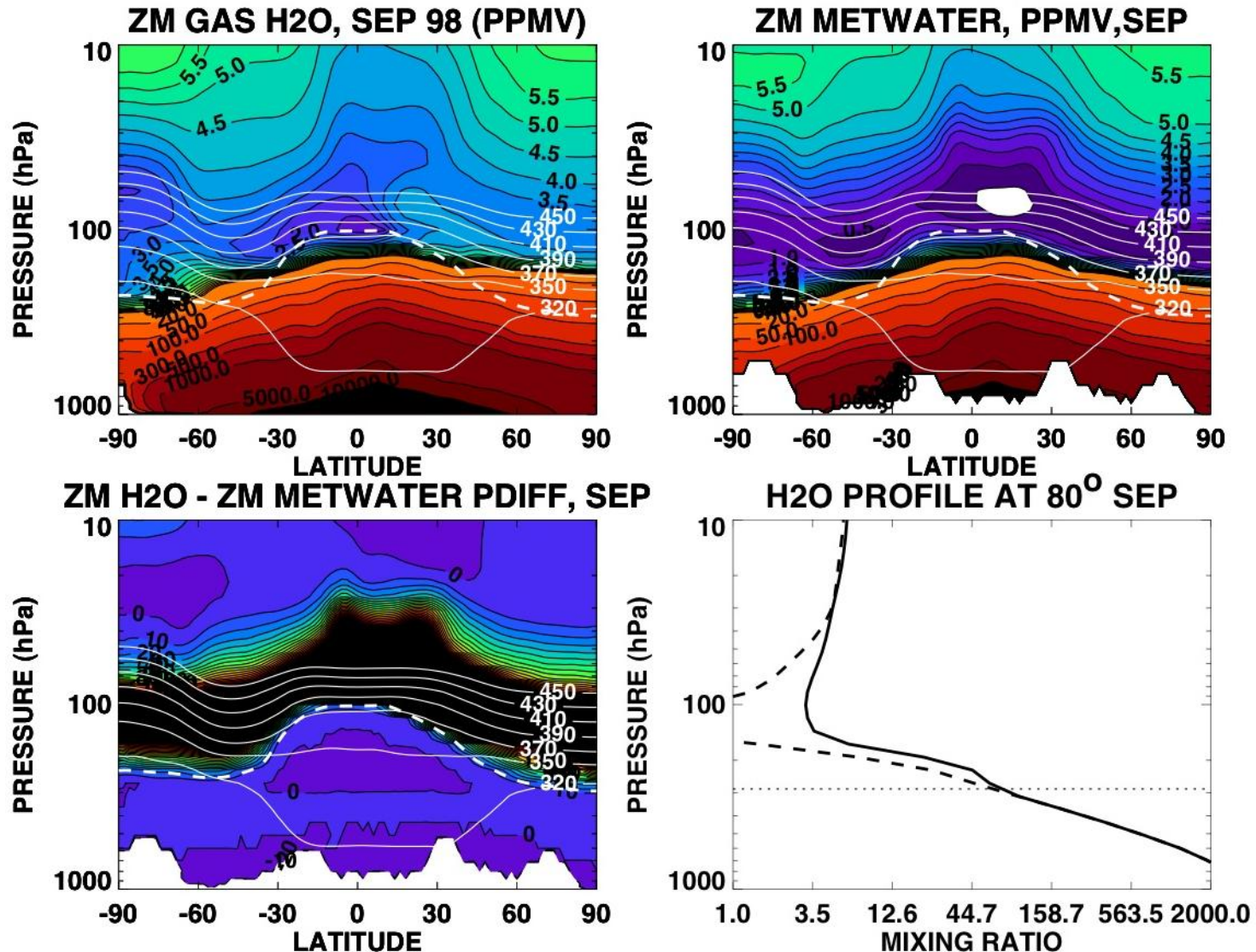
**O3 AT 350 K****MLS V2 O3 AT 350K**

- At 350 K, Combo Model and MLS O<sub>3</sub> are in good agreement at high lats, as shown for v 1.5 MLS data in Strahan et al. [2007]. High lat fall O<sub>3</sub> minimum not as low in Combo model as is observed (Consistent with Strahan et al. [2007].)
- High bias in Combo H<sub>2</sub>O at high lats would suggest concurrent low bias in O<sub>3</sub> if purely excessive isentropic transport caused H<sub>2</sub>O high biases.
- Summer/fall O<sub>3</sub> high-bias in model may be due to insufficient isentropic transport from lower latitudes.
- Note good agreement in tropics; Strahan et al. [2007] found v 1.5 MLS high-biased with respect to Combo model.

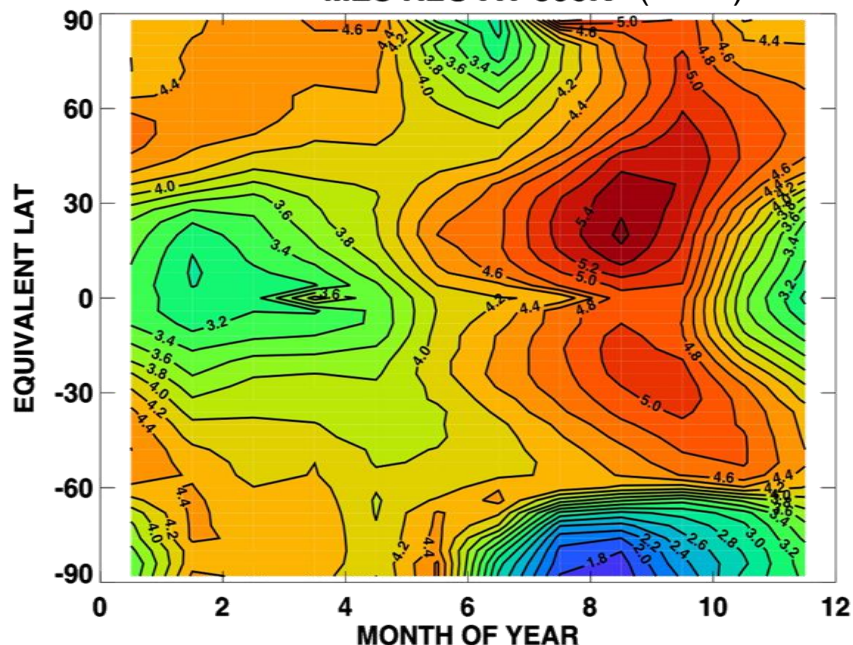
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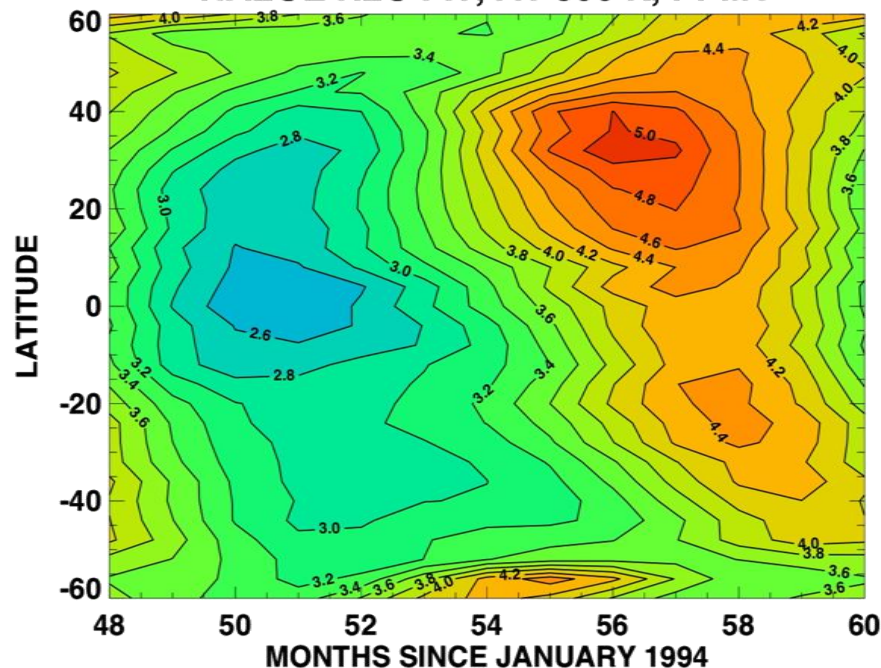
**Effects of GEOS 4 DAS met fields.** GEOS 4 DAS uses TOVS moisture retrievals above 200 hPa, where it is very dry and there is no information. GEOS 4 DAS cold point temps are lower than GEOS4 AGCM, leading to low water vapor values in tropical lower stratosphere.



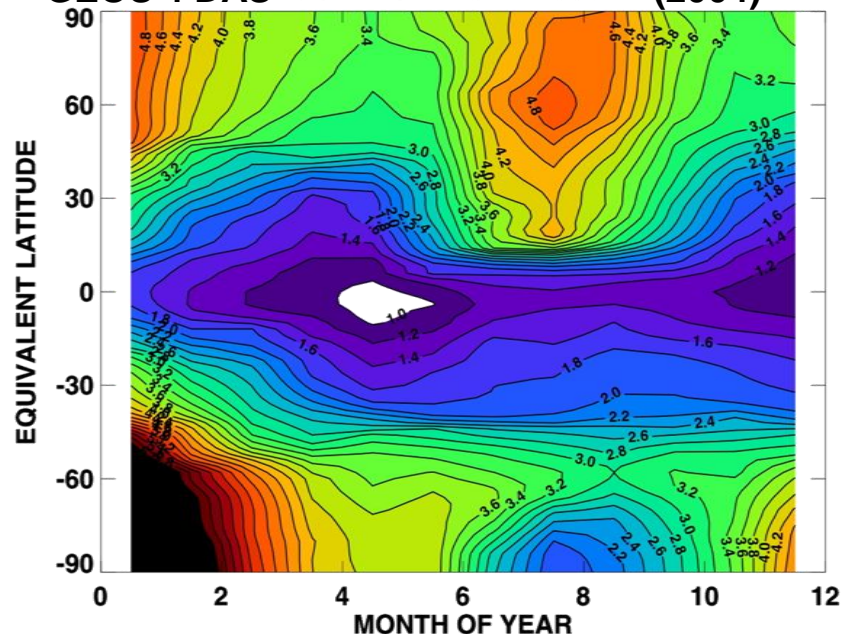
**MLS H2O AT 390K (2007)**



**HALOE H2O FIT, AT 390 K, PPMV**



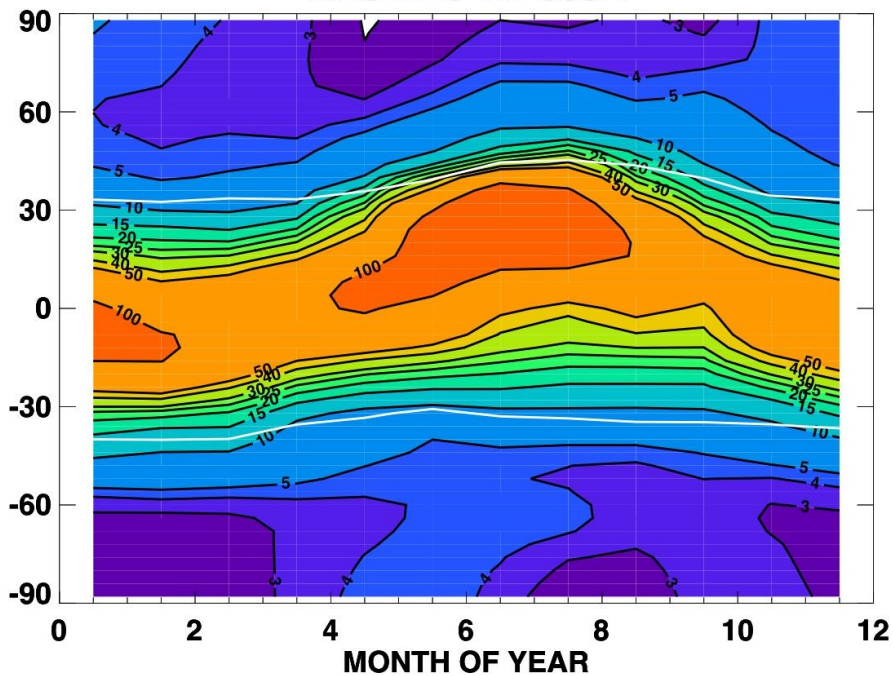
**GEOS 4 DAS COMBO H2O AT 390 K (2004)**



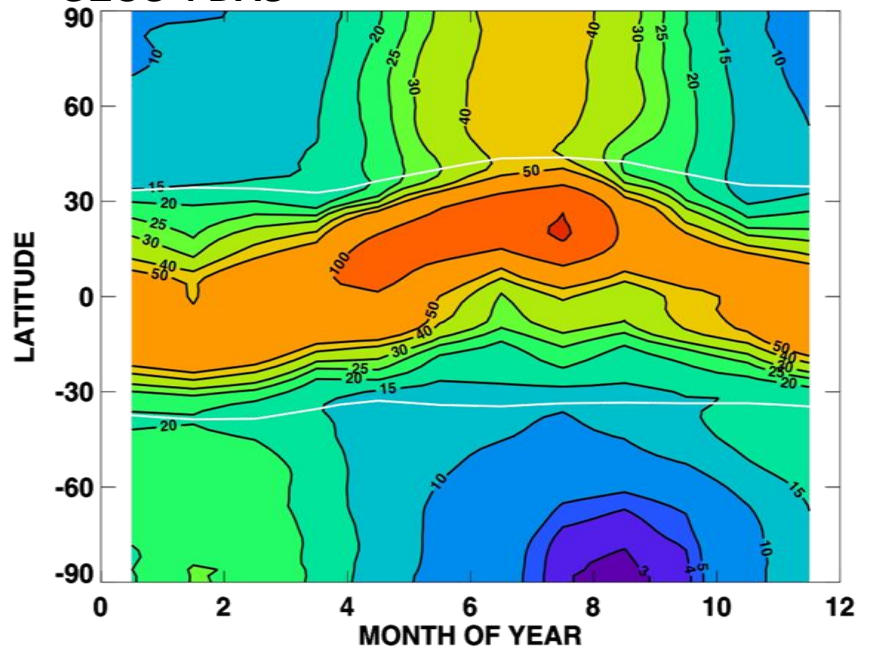
## EFFECTS OF GEOS 4 DAS MET DATA

When driven by the GEOS 4 DAS met data, annual cycle of H2O at base of overworld shows much lower than observed mixing ratios in the tropics due to the ~5 degree colder temperatures than seen in GEOS 4 AGCM. This degrades agreement with observations shown above.

**MLS H2O AT 350K**

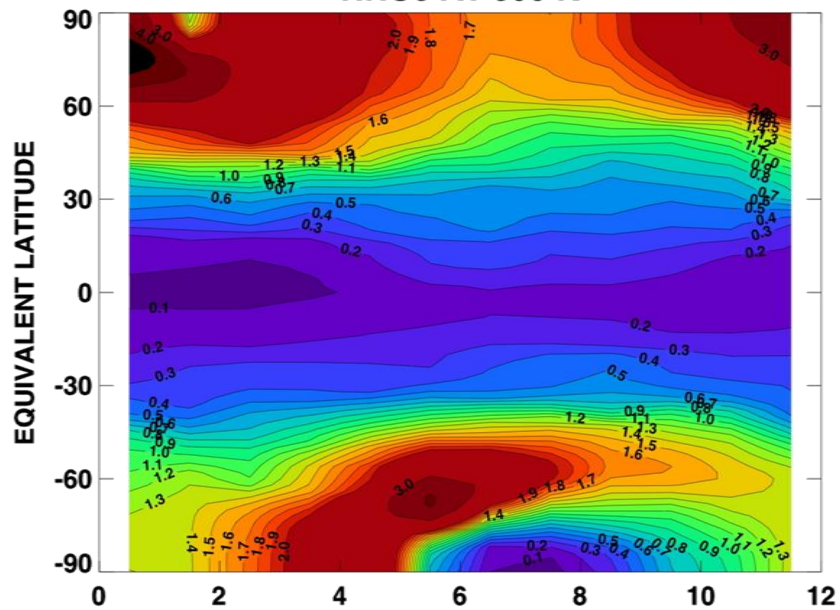


**GEOS 4 DAS COMBO H2O AT 350 K**

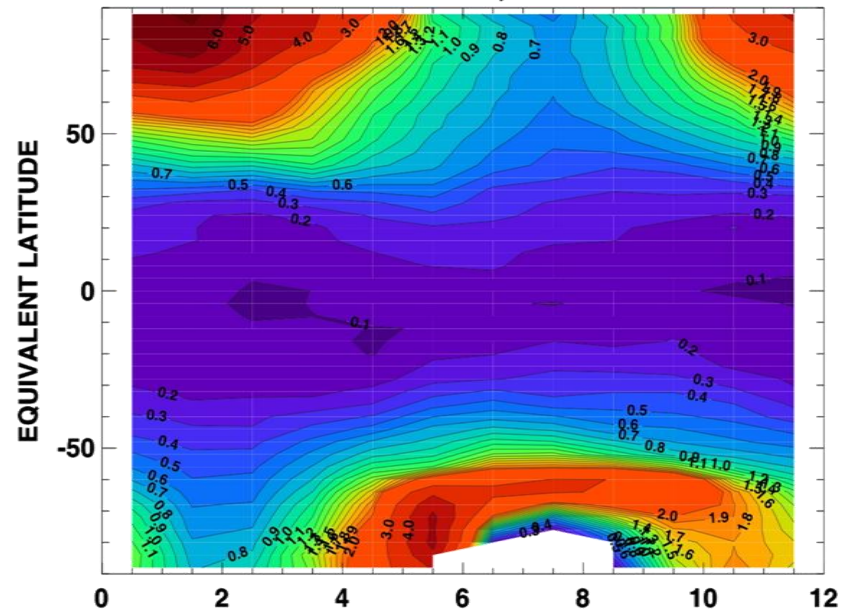


GEOS 4 DAS H2O on the 350 K surface agrees better in the tropics with MLS obs than GEOS 4 AGCM. However, There is more H2O in summer extratropics than in GEOS 4 AGCM or seen in MLS observations. Could be excessive isentropic transport or anomalous vertical transport.

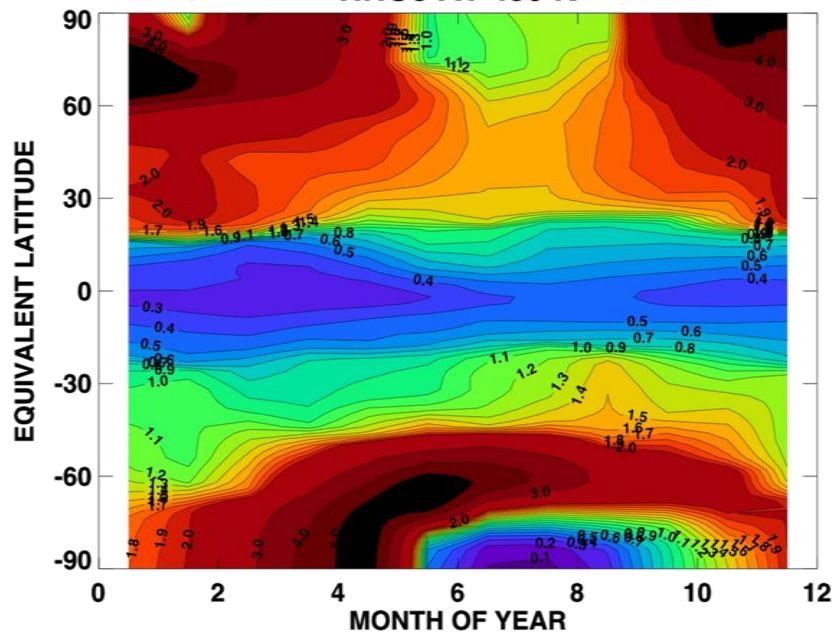
**HNO<sub>3</sub> AT 390 K**



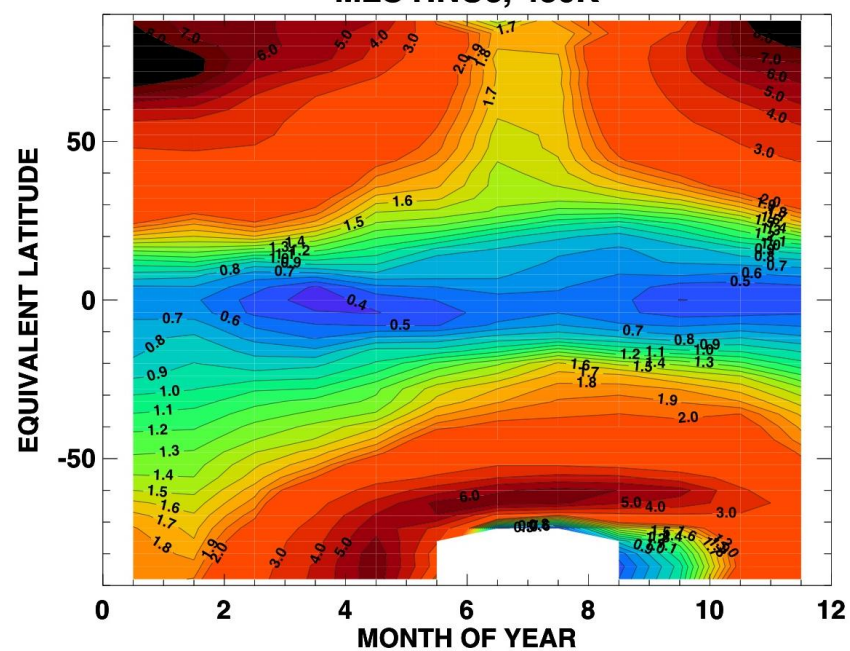
**MLS HNO<sub>3</sub>, 390K**



**HNO<sub>3</sub> AT 430 K**



**MLS HNO<sub>3</sub>, 430K**



# Conclusions

1. Using G4AGCM met data, good simulation of H<sub>2</sub>O in stratospheric overworld.
  - Model generates reasonable polar dehydration.
  - Tape recorder signal is good:
    - Overly coherent signal above 30 km understandable given lack of QBO in met data (what about SAO?)
  - Stratospheric H<sub>2</sub>O mixing ratios not bad.
  - Annual cycle of H<sub>2</sub>O at base of overworld (390 K) resembles patterns seen in MLS and HALOE obs, but suggestion of weaker isentropic poleward transport than seen in observations.
2. Simulation of H<sub>2</sub>O in LMS shows deficiencies.
  - Mixing ratios appear to be too high (but MLS is dry-biased relative to AIRS by 50% at low H<sub>2</sub>O, so might not be so bad).
  - High H<sub>2</sub>O appears to be due to excessive UT H<sub>2</sub>O in met H<sub>2</sub>O field, rather than excessive isentropic cross-tropopause transport - O<sub>3</sub> is not correspondingly low.
3. HNO<sub>3</sub> annual cycle in lower stratosphere compares well to MLS:
  - Polar denitrification in Combo model is reasonable.
  - Summer high lat NH mixing ratios 2x high - why?
4. GEOS 4 DAS LMS more high-biased relative to obs, very low tropical lower stratosphere mixing ratios. Not as good a simulation as GEOS 4 AGCM